

NJDOT Bureau of Research
4th QUARTER REPORT

Project Title:	A Comparison and Analysis of KA-Band Radar Vs. X-Band Radar			
RFP NUMBER: Project 2007-16	NJDOT RESEARCH PROJECT MANAGER: Edward S. Kondrath			
TASK ORDER NUMBER: 6	PRINCIPAL INVESTIGATOR: Allen Katz			
Project Starting Date: 1/ 1/ 2007 Original Project Ending Date: 12/31/2007 Modified Completion Date:	Period Starting Date: 10/ 1/ 2007 Period Ending Date: 12/31/2007			

Task	% of Total	% of Task 4th quarter	% of Task to date	% of Total Complete
Literature Search	5%	0%	100%	5%
1. Examine the state of development of Ka-band Radar	10%	5%	100%	10%
2. Prove/disprove Ka-band Radar is as reliable as X-band radar	30%	10%	100%	30%
3. Statistically validate radar testing approaches	25%	10%	100%	25%
4. Develop specifications for Ka-band radar meeting requirements of the Court system	10%	70%	100%	10%
5. Examine the state of development for Laser-band Radar	10%	20%	100%	10%
6. Final Report	10%	100%	100%	10%
TOTAL	100%			100%

Project Objectives:

1. Examine the state of the art in model development for Ka-band Radar.
2. Prove or disprove that the new technology (Ka-band Radar) is at the least as reliable as the current (X-band radar).
3. Identify data deficiencies and the statistical validity of alternative approaches.
4. Develop specifications and standards for Ka-band radar for all the requirements that are imposed by the Court system to be accepted as an instrument that measures speed.

Added Objectives:

5. Examine the state of the art in model development for Laser-band Radar.

Project Abstract:

This project focuses on the New Jersey State Police commitment to highway safety by enforcing posted speed limits. Effective enforcement of speeding statutes requires measured speed to be accurate and state of the art. This requirement is necessary in order to successfully prosecute by using both moving and stationary radar.

The New Jersey State Police currently utilizes MPH Industries K55 X-band radar units. The New Jersey courts have taken judicial notice as to the scientific reliability of the K55 radar. The advent of new Ka-band Radar technology now allows smaller and safer radar units to be employed. To successfully utilize these new Ka-band Radar units their speed measurement accuracy must be established in a scientific manner that will be accepted by the New Jersey courts.

The purpose of this research project will be to 1) establish a program for testing the performance of the new Ka-band radar units relative to the present K55 radar, 2) monitor the implementation of this testing program, 3) review the test results, 4) provide conclusions on performance and 5) document these conclusions in way they will facilitate the employment of Ka-band radar by the New Jersey State Police.

The relative characteristic and performance of available Ka-band radar units will also be investigated and documented.

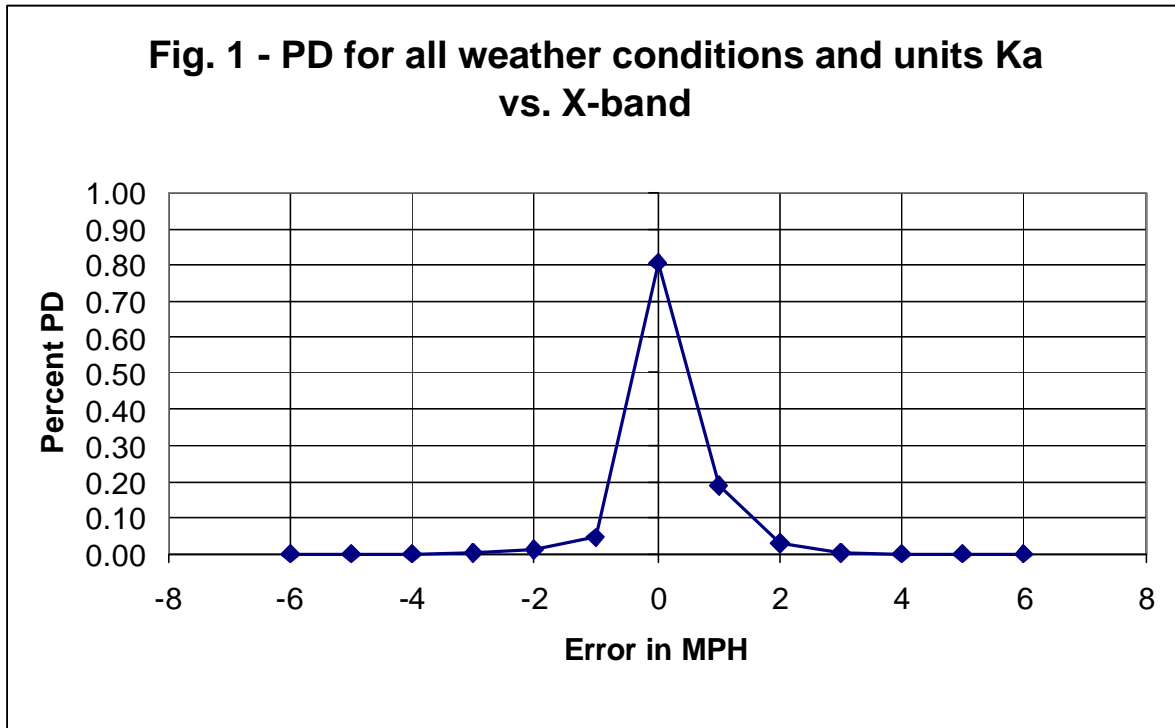
New and innovative programs like the introduction of the Ka-band radar speed detection devices will enable the Division of State Police to enhance their speed enforcement program to better serve the motorists who travel New Jersey's highways.

1. Progress this quarter by task:

- a) Examine the state of development of Ka-band Radar – A majority of this task was completed in the first quarter. In this quarter we continued to search the literature for any new developments related to traffic radar and maintain contact with representatives of both Stalker and MPH to discuss the questions relating to the operation of their radar units need for the final report. We also reviewed and finalized our analysis of the relative merits of these two competitive radar systems.
- b) Prove/disprove Ka-band Radar is as reliable as X-band radar – The majority of the field testing of Ka-band radar units produced by Stalker and MPH was completed in the previous quarters. In this quarter to include data in bad weather conditions from a moving vehicle, an additional 100 measurements of the MPH BEE III radar unit in rain were taken. (During the quarter an additional 200 laser radar measurements were also completed). During this research over 1,000 comparative measurements were taken. 200 of these measurements were made from a moving vehicle; 100 with the MPH Ka-band radar unit (BEE-III) and 100 with the Stalker Ka-band radar unit. A 100 of these were taken during rain. 300 additional measurements were taken under bad weather conditions from a stationary location; 200 with the MPH Ka-band radar unit and 100 with the Stalker Ka-band radar. These measurements were taken to add to our study of the effects of weather on Ka-band vs. X-band Doppler Radar

performance. In all cases the Ka-band measurements were compared to the reference MPH K55 X-band radar unit.

- c) Statistically validate radar testing approaches – The results of the forth quarter tests were consolidated with the data from previous quarters and statistically analyzed. The results of this analysis are shown in the following figures.



This figure shows the probability density (PD) of the difference between the reference X-band radar unit and the results obtained for both the Stalker and MPH Ka-band radar units under all weather conditions and includes both stationary and moving data. It can be seen that the agreement is excellent. Radar units are to be accurate within ± 3 mph with virtually no errors greater than 1 mph observed.

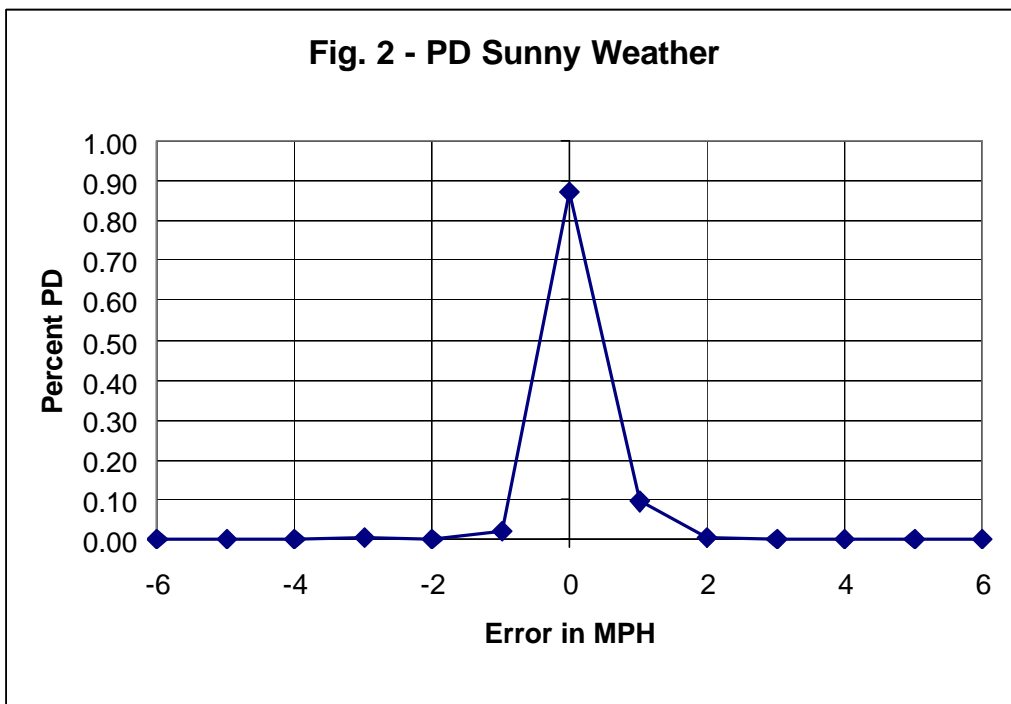


Figure 2 shows the PD for measurement during just fair weather conditions. There is no change in this result from the fourth quarter measurements. As might be expected the results are even better than for the all weather conditions.

The next graph, Figure 3, shows the results for bad (cloudy/wet) weather based on both Stalker and MPH Ka-band radar measurements including measurements taking while moving. Although slight less than for all weather, there is still excellent correlation between the X and Ku measurements. The accurate is still well within ± 3 mph with almost no errors greater than 1 mph observed.

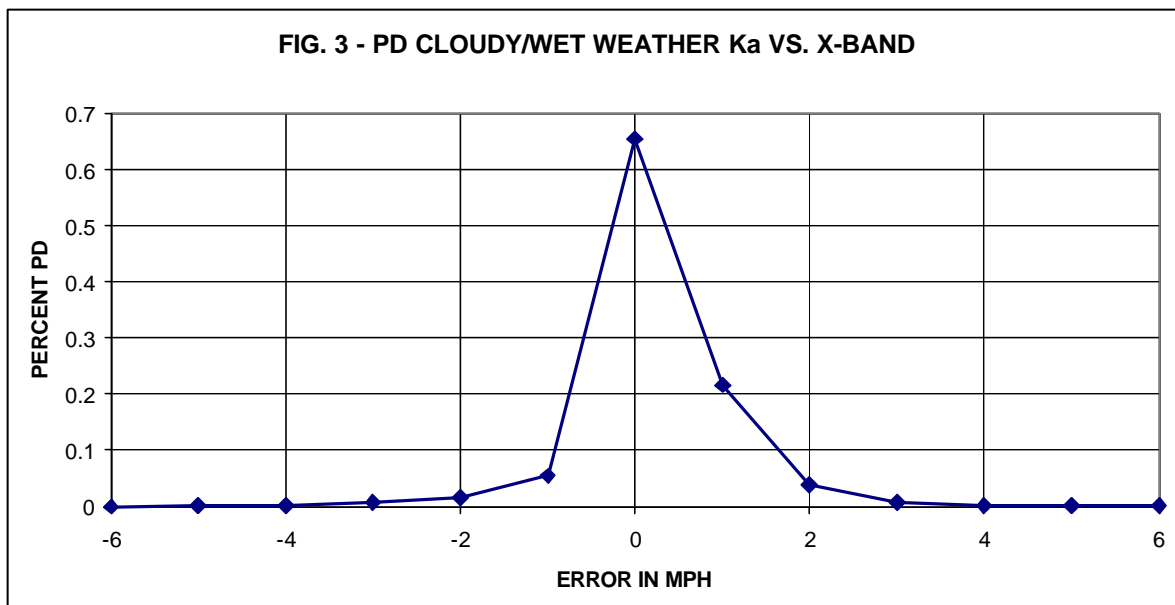


Figure 4 shows the effect of snow on the measurements. There is no change in this figure as a result of forth quarter data. These results are based on only Stalker measurements as there was no opportunity to get additional measurements in snow. The fact that this data was taken only with the Stalker Ka-band unit should not bias these results as shown by later comparisons both units offer very comparable performance. Based on the accumulated data, Dr. Guida sees no significant degradation at Ka-band in performance under different weather conditions.

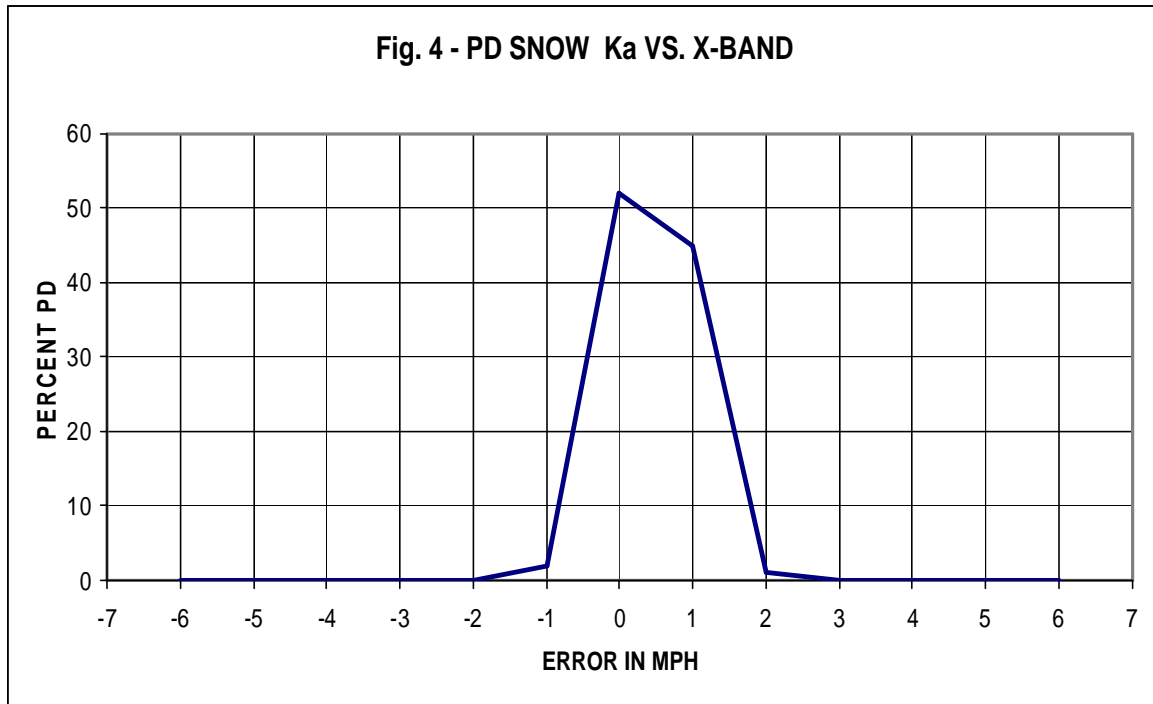


Figure 5 shows a comparison of the measured performance of the MPH and Stalker Ka-band radar units in comparison the X-band K55 reference under all conditions. Although the errors of the Stalker appear slightly smaller, this difference is believed to be due to small calibration errors that cannot be totally eliminated. Both units performed well with in the specified measurement uncertainty.

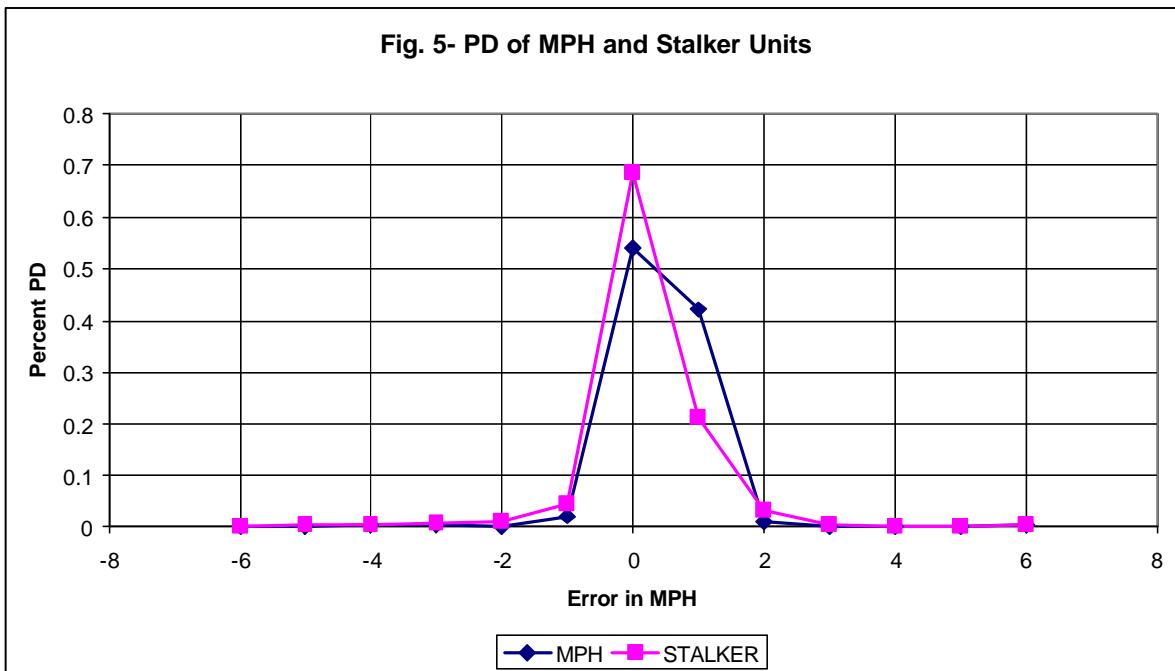
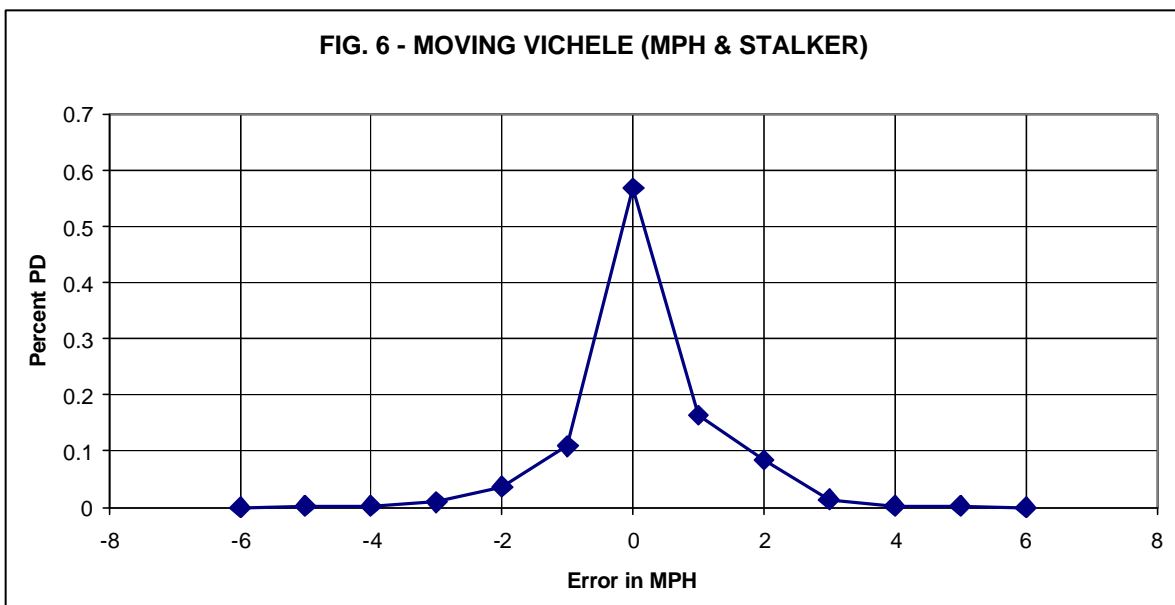


Figure 6 shows the results of measurements taken with both Stalker and MPH Ka-band radar units while in motion, and include the latest measurements during rainy conditions. Although these measurements show greater variance than stationary results, there is still good correlation between the X and Ku measurements. The accuracy is still well within ± 3 mph with almost no errors greater than 1 mph observed.



- d) Develop specifications for Ka-band radar that meet the requirements of the Court system
 – During this quarter a meeting with Mr. Dell' Aquilo from the State's Attorney General's office was held. Mr. Dell' Aquilo confirmed that the K55 X-band radar is the legal standard in New Jersey, and that comparing all measurements to this radar was appropriate and would be an effective way of substantiating the study's results in court.

He provided a copy of a 1998 New Jersey Superior Court Proceedings dealing with the validity of Laser Speed Detection, which he suggested could be used as a model for our study. This document was studied and used as a reference for the presentation of the results in the final report. He commended the use of a group that is independent of the State to conduct the study and felt that the use of real traffic conditions added to the study's credibility.

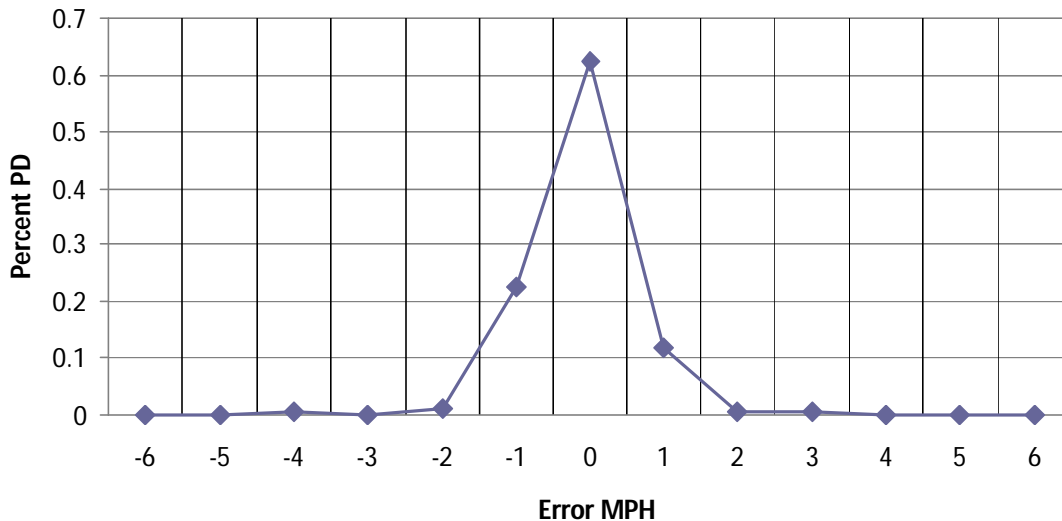
Mr. Dell' Aquilo suggested that the publication of the results of the study was another way of increasing the report's credibility and validating the results. Dr. Katz is submitting a paper on the study's results to the IEEE 2008 Sarnoff Symposium.

It is clear from the statistical results that both types of Ka-band radar will more than meet the accuracy requirements imposed by the law. The relative technical and operational merits of the Stalker and MPH Ka-band radar units have been reviewed. It was agreed that there are no significant differences between the measured performances of both units. The MPH displays a slightly smaller standard deviation than the Stalker unit, but this difference could be due to small calibration errors that cannot be totally eliminated. All units performed well within the specified measurement uncertainty (± 3 MPH). The Stalker radar offers the advantage of simultaneously displaying the speed of vehicles located both in front and in back of a patrol car. The MPH radar displays either, but requires the operator to manually switch the display from one direction to the other. The MPH is slightly smaller in size.

- e) Examine the state of development for Laser-band Radar – A search of Laser based radar literature was completed in an earlier quarter and manufacturers of laser based radars have been contacted. During this quarter an additional 100 laser radar measurements were completed to bring the total to 200.

Some learning is required to take accurate laser radar measurements as the operator must make certain that the laser unit is pointed at the same vehicle as the X-band radar is responding to. Figure 7 shows the results of laser radar testing without the first set of laser radar measurements to eliminate learning errors. It corresponds to a total of 160 measurements and includes measurements added during this quarter. These results are comparable to the Ka-band radar measurements showing excellent correlation with the X-band results. The accuracy is well within ± 3 mph with virtually no errors greater than 1 mph observed.

Fig. 7 - PD Laser Radar



2. Conclusion:

All objectives of the study have been completed and work on the final reported is under way.

- a) Examine the state of development of Ka-band radar -- This part is completed.
- b) Prove/disprove Ka-band Radar is as reliable as X-band radar – More than 1,000 measurements in all types of weather, with actual highway traffic prove that the measurements at Ka-band correlate closely with the X-band radar measurements (< 3 MPH error) and are well within National Highway Traffic Safety Administration (NHTSA) standards for both MPH and Stalker radar units.
- c) Statistically validate radar testing approaches – The statistical analysis has been completed and graphically illustrated to demonstrate the excellent performance of available Ka-band radar units.
- d) Develop requirements for Ka-band radar meeting requirements of the Court System – A list of specifications and complimentary data to prove the accuracy and reliability of Ka-band radar measurements is included in the final report in a format that will meet the needs of the New Jersey Court System, the State Attorney General's Office and the State Police.
- e) Examine the state of development for Laser-band radar – 200 independent laser measurements were taken that compliment and substantiate earlier work in New Jersey that prove the accuracy of speed laser measurements.

3. List of deliverables provided in this quarter by task (product date):

- a) Fourth Quarterly Report – was completed on 12/27/07
- b) Monthly reports – It was agreed that meeting minutes would be used in place of monthly reports and were completed on 11/02/07, 11/07/07 and 12/3/07 respectively. These minutes are in Appendix I.
- c) Final report is near completion and will be submitted before the end of the year.

4. Progress on Implementation and Training Activities: Not applicable to this project.

5. Problems/Proposed Solutions: None. Desired evaluation of laser radar units was voluntarily accepted as part of this research project.

6. Invoice Summary

Invoice Summary Page

<u>Task No.</u>	<u>Task Description</u>	<u>Percent of Total Project Budget</u>	<u>Total Project Cost</u> \$ 49,837.00 <u>Cost of Task</u>	<u>% of task this quarter</u>	<u>Cost this quarter</u>	<u>% of task to date</u>	<u>Total to date</u>
1	Literature Search	5%	\$2,491.85	0%	\$0.00	100%	\$2,
2	Examine the state of development of Ka-band Radar	10%	\$4,983.70	5%	\$249.19	100%	\$4,
2	Prove/disprove Ka- band Radar is as reliable as X- band radar	30%	\$14,951.10	10%	\$1,495.11	100%	\$14,
3	Statistically validate radar testing approaches	25%	\$12,459.25	10%	\$1,245.93	100%	\$12,
4	Develop specifications for Ka-band radar meeting requirements of the Court system	10%	\$4,983.70	70%	\$3,488.59	100%	\$4,
5	Examine the state of development for Laser- band Radar	10%	\$4,983.70	20%	\$996.74	100%	\$4,
	Final Report	10%	\$4,983.70	10%	\$4,983.70	0%	\$4,
		100%	\$49,837.00		\$49,837.00		\$49,

7. Summary:

- Examined the state of development of Ka-band Radar – Completed last quarter.

- Data shows Ka-band radar is as reliable as X-band radar – > 1,000 Measurements taken that show Ka-band accuracy within ± 3 mph with virtually no errors > than 1 mph. Additional measurements were taken in rain under moving conditions. Completed this quarter.
- Statistically validated radar testing approach – The results of the first, second, third and fourth quarter tests were consolidated and statistically analyzed. Task completed.
- Examine the state of development for Laser-band radar – 200 laser radar measurements have been taken. Task completed.
- Status - Project is completed on schedule and in budget. Final report will be submitted by end of year.

8. Appendix I Meeting Minutes

Ka-band Radar Research Meeting Minutes, November 2, 2007

Present: Sgt. Greg Williams, NJ State Police; Dr. Allen Katz, TCNJ/LTI and Dr. Allan Guida, LTI

This meeting was held at the offices of Linearizer Technology to review the project status and plans. (The meeting was originally scheduled for October 19th, but had to be rescheduled due to travel problems).

1. The meeting planned with the Attorney General's office was discussed. Due to the availability of the Deputy Attorney General, the meeting planned for October had to be delayed. It is now scheduled for 1 pm Wednesday November 7th at the TCNJ School of Engineering Dean's conference room. This meeting will discuss how best to present the data on the accuracy of the new Ka-band radars so as to support the needs of the Attorney General's office. The meeting will be with John J. Dell' Aquilo.
2. Sgt. Williams reported that he has been reassigned from the Operations Safety Bureau's Safe Passage Corridor Unit to the Community Services Unit to supervise the central squad of Community Service Personnel, but that he would continue with the project until it is concluded. He said he was very pleased that we have accomplished so much with the Radar Research Project.
3. Sgt. William also reported that he had completed 200 additional laser measurements. One hundred of these measurements were made in light rain. He observed that these laser radar measurements showed better correlation with the X-band radar as a result of his experience with earlier measurements.
4. Dr. Katz reported that he and Dr. Guida have completed the statistical analysis of the previous data and will work have the analysis of the current data completed in the next two weeks.

5. There was a general discussion on how best to take laser measurements and the need for training to synchronize the X-band and laser measurements.
6. Sgt. Williams reporting that there may be an opportunity to meet with representatives of MPH Radar who are expected to be visiting the area in the next few weeks.
7. Our next meeting, after the one with Attorney General's office, will be scheduled for the end of November to discuss the final report.

Ka-band Radar Research Meeting Minutes, November 7, 2007

Present: Sgt. Greg Williams, NJ State Police; Dr. Allen Katz, TCNJ/LTI and John J. Dell' Aquilo, Attorney General's office

This meeting was held at the School of Engineering Dean's Conference Room at The College of New Jersey to review the study's results and insure they are in a format that is most effective for use in the New Jersey Court system.

1. Dr. Katz distributed copies of the sections of the 3rd Quarter Progress Report dealing with the radar test results and their statistical analysis. He discussed these results and how the measurements were taken. He reported that all measurements were made in comparison to a MPH K55 X-band radar unit, that more than 1,000 measurements had been taken in different forms of weather including rain and snow, that all measurements were made under actual traffic conditions with a variety of vehicles and with the two leading Ka-band radar units.
2. Mr. Dell' Aquilo noted that the K55 X-band radar is the legal standard in New Jersey, and that comparing all measurements to this radar was appropriate and should be an effective way of substantiating the study's results in court. He felt having the study conducted by a group that is independent of the State and the use of real traffic conditions added to the study's credibility.
3. Mr. Dell' Aquilo suggested that the publication of the results of the study was another way of increasing the report's credibility and validating the results. Dr. Katz said he would investigate appropriate venues for publishing the study's results and that publication should be achievable.
4. Mr. Dell' Aquilo distributed a copy of a 1998 New Jersey Superior Court Proceedings dealing with the validity of Laser Speed Detection that could be used a model for our study.
5. Dr. Katz discussed technical issues (as antenna pattern and beamwidth) that could affect a radar's performance. He said the technical specifications of the radar units used in the tests would be included in the final report.
6. Mr. Dell' Aquilo suggested that the specifications should be referenced to the standards of the National Highway Traffic Safety Administration (NHTSA). He also recommended Steve Ritter as a contact for highway traffic safety information.
7. Dr. Katz and Sgt. Williams thanked Mr. Dell' Aquilo for his time and very valuable assistance.

8. The next meeting is planned for November 30th to discuss the final report.

Ka-band Radar Research Meeting Minutes, December 3, 2007

Present: Dr. Allen Katz, TCNJ/LTI and Dr. Allan Guida, LTI

This meeting was held at the offices of Linearizer Technology, Inc. Sgt. Williams was not in attendance because of his new position responsibilities, but sent by post data completed the planned radar test measurements.

1. Drs. Katz and Guida reviewed new data of 100 laser measurements taken in sunny weather conditions and 100 MPH BEE III Ka-band radar measurements taken from a moving car in light rain. It was noted that the laser measurements showed good correlation to the X-band radar unit and were similar to the second set of 60 measurements taken in the last quarter. Dr. Guida will statistically analyze these measurements.
2. Plans for the final report were discussed. Dr. Katz will do the majority of organizing and writing. Dr. Guida will complete the statistical analysis and review the results.
3. It was noted that the final report is due before the end of the year.